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Emerald Article: Risks associated with chemical treatment residues in buildings

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Abstract

Past and current uses of chemical treatments to control or eradicate fungal infections and/or insect infestations in buildings have led to a number of reported cases where occupants and users of these buildings have suffered various physical symptoms. The role of chemical treatments, whether as biocides, fungicides, insecticides or wood preservatives, has therefore come under scrutiny and various countries are now reviewing their use in favour of a more benign approach to the management of decay in buildings. Growing concern for the environment and the health of those treating or living in treated buildings has also led to changes in the way we perceive and deal with buildings and building defects. As a result, the conventional approach to survey, defect diagnosis and remediation has to be re-thought and placed in the context of a wider environmental agenda. This paper provides evidence for how historic chemical treatments can have effects on the health of the building and its occupants, and considers the implications of such treatments for those charged with specifying or undertaking works to the fabric of affected buildings.

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Introduction

The selection and use of chemical treatments for the control or eradication of fungal infections and/or insect infestations in buildings has been reported in general surveying texts (Bravery *et al.*, 1987, pp. 109-13; Melville and Gordon, 1973, pp. 419-21, 430-31; TRADA, 1991a), and in a number concentrating on the repair and maintenance of historic buildings (Ashurst and Ashurst, 1988, pp. 1-9; Brereton, 1991, pp. 13, 31-5; Feilden, 1994, pp. 134, 150; Insall, 1972, pp. 122–25; Weaver, 1993, pp. 46-57). There are also sources of information relating to the identification and control of infestations in the contents of buildings and museums (Harrison, 1994, pp. 162-69; Pinniger, 1994; Sandwith and Stainton, 1991, pp. 191-93).

It is clear, however, that the problems of chemical treatment residues in buildings have not been widely considered or reported. Of the few papers that have been published, most have concentrated on the continuing role of remedial treatment companies in providing a service to building owners and their professional advisers (Howell, 1995; Murray, 1992; Oxley, 1995), rather than on the problems posed by previous treatments.

There is, moreover, a growing realisation that chemical treatments may have implications for those property professionals responsible for advising on the condition of existing buildings to clients and lending institutions. Questions relating to duties of care, liability and professional indemnity insurance have been raised (Anon, 1986; Howell, 1996a, 1996b), and the suggestion made that building surveys and inspections should identify previous chemical treatments (Howell, 1996c).

At a broader level there is concern currently being expressed about the use of deleterious materials in the construction industry (Maycox, 1997), and the presence of such materials in existing buildings (Watt and

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Swallow, 1996, p. 241). Such concerns typically relate to the liability of clients, designers, principal contractors and contractors under the Construction (Design and Management) Regulations 1994, and to a growing environmental awareness promoted by pressure groups and professional organisations.

Greater regard for building pathology and the adoption of holistic approaches to building maintenance and management, particularly for historic buildings and monuments, have led to a growing interest in benign and environmentally-friendly methods of managing decay. This has been particularly prevalent in the selection of alternative materials (Curwell and March, 1986; Harland, 1993, pp. 163-212), the management of timber decay (Ashurst and Ashurst, 1988, p. 5; Hutton *et al.*, 1991; Jernberg *et al.*, 1996; Lloyd and Singh, 1994; Singh and White, 1995), and issues of indoor air quality (Crowther, 1991; Curwell *et al.*, 1990; Singh, 1993; Singh and Walker, 1996a).

As more becomes known about the effects of chemicals on human health, and the sensitivity of persons to single or multiple chemical exposures, there is a growing body of information from the medical and legal professions on the effects that chemical treatments and treatment residues might have on the health of buildings and their occupants (Breakspear Hospital, 1993, 1994, n.d.; Brimacombe, 1988; Care, 1992, 1993, 1994, 1995; Care and Day, 1995; Day and Care, 1995; Driver and Whitmyre, 1996; Duehring, 1997; Green Network, 1996; Horton, 1997; Lawson, 1989; Nemeskeri *et al.*, 1991). This, in turn, is being matched by an increase in scientific research, linking exposure to symptoms (Jorens and Schepens, 1993; Laurance, 1997; Meißner and Schweinsberg, 1996; O'Malley, 1997; White and Proctor, 1997).

Coverage given to the practical decontamination of treated buildings, or to the containment of treatment residues, has been limited. Of the "ten important pesticide issues" cited by the Pesticides Trust (Pesticides Trust, 1990, p. 5), the link between pesticide residues and health, and particularly the chronic long-term effects of low doses, have been identified as requiring greater study. This includes improved monitoring of residues and clear policies of risk assessment.

Chemical treatments within buildings

Extent of chemical treatments

The term "pesticide", as defined by the Food and Environmental Protection Act 1985, describes "any substance, preparation or organism prepared for or used, among other uses, to protect plants or wood or other plant products from harmful organisms; to regulate the growth of plants; to give protection against harmful creatures; or to render such creatures harmless". As such, it embraces herbicides, fungicides, insecticides, rodenticides, soil-sterilants, wood preservatives and surface biocides (MAFF/HSE, 1997, p. 1).

Of the many types of indoor air pollutants that have been identified and reported, the use of chemical treatments, including pesticides, has attracted particular attention. Surveys in the USA have shown, for instance, that 75 per cent of households used at least one pesticide product indoors during the period of one year, and that measurable levels of up to a dozen pesticides have been found in the air inside homes (EPA/CPSC, 1988).

Estimates of the number of properties that have received chemical treatments for the control or eradication of fungal infections and/or insect infestations are difficult to ascertain. In 1983 it was estimated that there were "roughly 100,000 [remedial] treatments conducted annually in the UK" (Dobbs and Williams, 1983, p. 272), while by 1989 it was considered that: "some 150,000 premises in the UK undergo remedial (*in situ* timber preservation) treatments per annum" (HSE, 1989, p. 1). More recent figures suggest that 200,000 *in situ* timber treatments are undertaken each year, with an estimated four million dwellings, or one-fifth of the total housing stock, having thus been treated during the past 25 years (Howell, 1996a, 1996b). Perhaps of greater concern is the suggestion that between 20 per cent and 25 per cent of treated properties receive multiple treatments (Howell, 1996a, 1996b).

The total number of buildings that have been, and are being, chemically treated, whether professionally or otherwise, is thus probably unknown. The presence of chemical treatment residues and the potential risks to the health of those associated with such buildings are similarly unknown.

Nature of traditional chemical treatments

Although chemicals have been used to control or eradicate fungal infections and/or insect infestations in buildings since the mid-nineteenth century, widespread availability of preservatives developed with the use of organic solvent carriers in the second quarter of the twentieth century (Hilditch, 1994, p. 213).

Traditional recommended treatment for infection by the dry rot fungus (*Serpula lacrimans*) has been based on the removal of decayed timber and the fungicidal treatment of affected masonry. Such treatments would typically have been based on sodium fluoride and magnesium silico-fluoride, although these are likely to be have been neutralised by: lime-based mortars; sodium pentachlorophenol; sodium orthophenylphenate; or pentachlorophenol (Melville and Gordon, 1973, p. 419).

Containment of the fungus within the wall was undertaken by the surface application of fungicidal fluid (sodium pentachlorophenoxide, sodium 2-phenylphenoxide or an aqueous mixture of an organo-tin and quaternary ammonium compound, but not magnesium silico-fluoride or sodium fluoride solutions as these are inactivated by contact with lime mortar), the use of fungicidal renderings (zinc oxychloride), preservative plugs or pastes, or irrigation with a fungicidal solution (BRE, 1985b, pp. 4-5).

Controlling outbreaks of wet rots would again be based on primary and secondary measures (BRE, 1989, pp. 10-11), although the need to treat masonry is negated by the nature of the fungi.

Treatment of retained and replacement timber would have been based on the use of tar-oil (coal tar creosote or coal tar oil for external use), water-borne (copper/chrome, copper/chrome/arsenate, sodium fluoride or borax) or organic-solvent-based (copper naphthenate, zinc naphthenate, pentachlorophenol and its derivatives, tributyl tin oxide, chlorinated naphthalene, lindane or dieldrin) preservatives (BRE, 1977, p. 2; TRADA, 1991b).

Treatment for infestation by wood-boring beetles would typically have made use of insecticides based on chlorinated hydrocarbons, such as dieldrin and lindane (Melville and Gordon, 1973, p. 430), and be divided between liquid treatments (organic-solvent-based liquids, emulsion-based liquids or mayonnaise pastes), smoke treatments, dichloruos vapour, gas fumigation and heat sterilisation (BRE, 1987, pp. 3-5).

The pre-treatment of replacement and new timber is dealt with in other publications (BRE, 1977, 1985a; TRADA, 1991c).

Chemical treatment residues within treated buildings

Preparation and protection

Although recognised as potential contaminants of indoor air, little appears to be known about chemical treatment emission rates from treated building fabric, dispersal and contamination of indoor air, and modelling of pesticidal active ingredients in the indoor environment (Spalding, 1997, p. 2.1).

While the nature and extent of preparation and protection given to buildings and their occupants prior to treatment has been widely documented, there has been little attention given to those persons for whom exposure to chemical treatments or to their residues might cause serious harm.

The British Wood Preserving Association, in its *BWPA Code of Practice for Remedial Treatment*, presented a “standard for the *in situ* treatment of insect and fungal infestation for the guidance of firms dealing in remedial treatment” (BWPA, 1983, section 1). In this, preparation prior to treatment included measures “to protect the property and its occupants”, based on the *BWPA Safety Precautions for Observance by Firms Engaged in Remedial Treatment*. This included removing all floor coverings, furniture, soft furnishings; protecting water tanks; removing or protecting thermal insulation in roof voids; isolating electrical circuits within the treatment area; protecting rubber covered cable, cable ends and junction boxes against the ingress of treatment fluids; and excluding persons not engaged in carrying out the treatment from the immediate vicinity during and immediately after spraying.

The Health and Safety Executive also issued guidance on the principal potential hazards to health, safety and the environment arising from the *in situ* remedial treatment of timber (HSE, 1989, p. 3). This included informing all persons who might be affected by the work about the products to be used and the risks involved; the possible need to evacuate inhabited buildings or segregate and isolate areas that could be affected; and considering the exposure of persons in adjoining premises, and the possible need for evacuation, isolation or segregation when working in flats, terraced or semi-detached property.

The Health and Safety Executive also recommended the protection of plastic drinking water service pipes from pesticide products and solvents, as contact might affect the durability of the pipes and in some cases lead to contamination of drinking water by permeation of the pipe walls. Dusts arising from the preparatory work were noted as possibly leading to a suspension of wood dust, fungi and other material into the air, which might cause respiratory disorders and skin complaints.

A guide to good practice, produced by the Health and Safety Executive and the Department of the Environment (HSE/DoE, 1991, p. 23) included a section on special precautions and evacuation procedures. It again stressed that if treatments were to be carried out in occupied buildings, it would be necessary to evacuate and isolate the affected areas in advance. Special precautions were seen to be needed for people with respiratory problems, or for the very old or very young, and specialist advice from the medical practitioner responsible for occupants recommended before work started.

The supervisor was also charged with checking whether other occupants of the building, or in nearby properties, suffered from respiratory conditions or allergies that might be triggered as a result of the remedial work being undertaken. If, despite all safeguards, a potential health risk remained and evacuation was impossible, the supervisor was to seek non-pesticidal alternatives for the remedial work.

Despite the assertions given in this last publication, there is growing evidence that such “special precautions”, “specialist advice” and “non-pesticidal alternatives” are not being fully considered, and the risks of chemical exposure remain.

Chemical treatment residues

Chemical treatment residues may be defined as that part of a treatment, whether active ingredient and/or carrier solvent, that remains after treatment. In the context of this work, it is these residues that have the potential for contamination and associated risks to the health of the building and its occupants.

Residential pesticide monitoring studies in the USA have demonstrated that measurable, though relatively low-level, residues do exist in treated buildings, and that indoor exposures are often higher than outdoor exposures (Fenske *et al*., 1990; Whitmore *et al*., 1994). In the case of timber treated with preservatives based on pentachlorophenol (PCP), it has been found that PCP is liberated for many years after initial treatment, and that contamination of untreated objects may occur within closed rooms following treatment (Jorens and Schepens, 1993, p. 480).

Growing medical evidence suggests that the effects of exposure to chemical treatments may be linked to the active ingredients and/or the carrier solvent within a particular treatment. Clinical evaluation has shown that acute systemic effects and local reactions may result from pesticide exposure and poisonings (White and Proctor, 1997), while solvents may cause serious long-term neurological damage (Hilditch 1994, p. 230; Laurance, 1997; White and Proctor, 1997). The possible synergistic (i.e. the combined effect is greater than the sum of the individual solvents)/ potentiating effects of active ingredients and carrier solvents also need to be considered.

Formation of treatment residues

Within an indoor environment, chemical treatments tend to divide into separate parts, either through direct dispersion in the indoor air or through adsorption on to surfaces from which material might subsequently be released into the air (Driver and Whitmyre, 1996, pp. 6-7). It might therefore be assumed that chemical residues exist in the form of “reservoirs” within the structure and fabric of a treated building, when the source of the chemicals has not been balanced by “sinks” such as ventilation and adsorption. The concept of reservoirs and sinks is one that is often used to explain the presence of moisture within buildings (Singh, 1993, p. 220; 1994, pp. 5-10), although data on the effect of untreated building materials and contents, which may act as sinks for pesticide active ingredients, is limited (Spalding, 1997, pp. 2.1.1).

The sources and manner in which chemical treatments reservoirs may form within a treated building are:

- release during treatment (e.g. spray-drift, overspray, run-off);
- emission following treatment (i.e. off-gassing);
- surface deposition;

- contamination (e.g. dust, debris, contents);
- spillage; and
- re-distribution (e.g. solvent washing).

Hazards and risks associated with chemical treatment residues

As growing concern and attention are being given to issues of indoor air quality, it is becoming clear that occupiers and users of buildings are being exposed to significant and increasing health risks due to the long-term and cumulative effects of indoor air pollutants. This risk is particularly severe for the young, ill and elderly, and for those that have become sensitised through previous chemical exposure(s). Increases in the levels of indoor air pollution and the corresponding risks of exposure have also been noted as being of greater significance than risks associated with corresponding outdoor pollutants (Wallace, 1993).

Factors influencing treatment residues

Exposure to the active ingredients and/or solvent carriers of chemical treatments, and the effects that such exposure(s) might have on the health of an individual or group, depend on various factors. It is possible to identify certain common issues that may warrant further consideration, although such factors are, in part, beyond the scope of this present work.

Building:

- spatial arrangement (i.e. cellular, open, deep-plan);
- forms of construction (e.g. traditional construction allows greater air movement through natural leakage and infiltration);
- building materials (i.e. porous/permeable nature of traditional building materials, nature of finishes);
- services and controls (e.g. air-conditioning, forced and passive stack ventilation);
- incidence of multiple treatment;
- presence of historic treatment residues;
- reservoirs and sinks (e.g. loft insulation, carpets, furnishings).

Environment:

- indoor conditions (i.e. ambient and surface temperature, relative humidity, air flow, light, noise);
- indoor air quality (i.e. levels of dusts, spores, particulates, allergens, pollutants);
- ventilation and air movement (i.e. air exchange rates with outdoors/other rooms, diaphragm action of suspended floors);
- micro-environments (e.g. pesticides and volatile organic compounds from consumer and commercial products) (Driver and Whitmyre, 1996, p. 6);
- sink effects (i.e. adsorption/desorption from various surfaces);
- presence of neighbouring treatments and treatment residues (e.g. flats, terraced or semi-detached property).

Chemical treatment:

- treatment variables (i.e. treatment method, operator error, poor maintenance/cleaning of equipment allowing cross-contamination);
- chemical and physical state of the substance (i.e. solid, liquid, gas, volatility, vapour pressure);
- chemical or physical transformation and/or degradation;
- rates of evaporation (Hilditch, 1994, p. 224);
- leaching by excess moisture (Lloyd and Singh, 1994, p. 160);
- air concentrations (Dobbs and Williams, 1983; Dobbs *et al.*, 1979);
- rates of emission and migration;
- peak concentrations of solvent carrier(s) and active ingredient(s) (Morgan and Purslow, 1973; Newsome, 1993).

Use and activity:

- levels of occupancy (i.e. single, multiple);
- human activity patterns (e.g. sleeping, eating, working, exercising);
- additional solvent/chemical usage (i.e. adding to total chemical burden);
- "personal cloud" of particles exposing individuals during daily activities (Wallace, 1993);
- re-suspension of particulate contaminants (e.g. household dust through walking, dusting, sweeping, vacuuming) (Driver and Whitmyre, 1996, p. 7);
- transfer from outside (e.g. contaminated soil).

Health and wellbeing:

- general influences (i.e. physical, chemical and biological) (Singh, 1993; Singh and Walker, 1996b, p. 63);
- exposure pathways (i.e. inhalation, dermal exposure, ingestion);
- duration and number of exposures;

- individual characteristics (e.g. age, sex, inhalation rates, skin surface area, body weight, pregnancy, previous illness, obesity [body fat], alcohol levels) (Croner, 1989, pp. 1-29);
- individual sensitivity (e.g. single or multiple chemical exposures, definition of nuisance);
- total allergy load (i.e. threshold level);
- individual susceptibility (Croner, 1989, pp. 1-29, 1-30);
- psychosomatic response (i.e. interaction of body and mind);
- idiosyncratic response.

Conclusions and recommendations

Health implications of chemical treatment residues

While early assertions that building occupants were "not at risk from the activities of properly conducted remedial treatments" (Coggins and Lothian, 1979) have proved to be largely true, there is increasing evidence to suggest that chemical treatments and associated residues may, however, have the potential for adversely affecting those who suffer from chemical sensitivity or are nearing the limit of tolerance (Burrell, 1997; Care, 1995; Crossley, 1996).

In the light of the World Health Organization's *European Charter on Environment and Health*, with its statement that every individual is entitled to "an environment conducive to the highest attainable level of health and wellbeing" and its principle for public policy that "the health of every individual, especially those in vulnerable and high-risk groups, must be protected" (WHO, 1989), more needs to be done to consider the risks attached to chemical treatments and their residues.

With regard to the health and wellbeing of persons using, occupying or working on treated buildings, employers are required to ensure the health and safety of employees and others under the Health and Safety at Work, etc, Act 1974, and to assess risks and hazards under the Management of Health and Safety at Work Regulations 1992, Management of Health and Safety at Work (Amendment) Regulations 1994, and Control of Substances Hazardous to Health Regulations 1994.

Under the Construction (Design and Management) Regulations 1994 there is a requirement that "details of risks to the health and safety of any person carrying out the construction work so far as such risks are known to the planning supervisor or are reasonably foreseeable" should be contained within the pre-tender health and safety plan. The question to be asked is whether the presence of chemical treatment residues, if known or reasonably foreseen, needs to be included within such a plan.

The answer would certainly be that it should, as would be the case with the presence of asbestos or contaminated ground. The level of enquiry required to identify the residue would need to be reasonable and appropriate for the particular set of circumstances, which might include the chemical sensitivity of those persons undertaking the work or using the building on completion.

Further, it is such information, and details of current treatments, that should also be included within the health and safety file for future owners and occupiers, and for the benefit of those involved in subsequent projects.

Building maintenance and management

Buildings should ideally work by themselves, without total reliance on toxic chemical treatments to control or eradicate fungal infections and/or insect infestations. Prevention, by limiting the moisture content of timbers and ensuring adequate levels of ventilation, is thus preferable to the cure. Such a passive approach to building maintenance and management requires a greater understanding of the mechanisms of deterioration and decay that affect buildings, and the ways in which they are used and abused.

Such a responsible approach should therefore take into account past and present chemical treatments, and associated treatment residues, in relation to the health of the building, and its current and future occupants.

Concepts of environmental control and management, such as put forward by Hutton *et al.* (1991); Lloyd and Singh (1994, pp. 174-75); Singh (1996); Singh and White (1995); Weaver (1993, pp. 55-6); need to be more widely recognised and adopted. The selective targeting of chemical treatments and consideration for the natural predators of wood-boring insects are two such subjects that are currently being addressed by English Heritage in relation to historic buildings and monuments (Teutonico, 1995, 1997). The results of this work, and the challenges that it might bring to present attitudes and practices, need to be considered by those instructing and undertaking remedial treatments.

Containment and decontamination

The containment of chemical treatment residues within treated building fabric would seem to offer a solution to the potential problems of long- and short-term emissions of solvent carrier and/or active ingredient. In this respect the use of appropriate paint films, plasters and other coverings, together with ventilation, may reduce the risk of exposure to negligible proportions in most houses (Anon, 1986).

The use of inorganic molecular sieve coatings on timbers treated with chlorinated pesticides has been shown to trap gaseous emissions, and offer the potential advantage of retaining the chemicals within the fabric, so prolonging their active life (Huddersman, 1995). Recent studies have shown that emissions may be reduced by up to 74 per cent, even after accelerated ageing equivalent to 18 months (Huddersman, 1997).

Coverage given to the decontamination of treated buildings or building fabric has been limited. This has typically been restricted to specific guidance (Daunton, 1995), reports of individual cases (London Hazards Centre, 1988, pp. 148-56), and reference to work carried out in the USA and Germany (Howell, 1995, p. 14).

Recent tests carried out by Thermo Lignum Limited® on the decontamination of museum objects and treated timbers are yet to be published (Nicholson, 1997; Von Rotberg *et al*., 1997), although the successful use of their thermal, inert gas fumigation and modified inert atmosphere systems for treating insect pest infestations in museum artefacts, collections and buildings has been reported (Nicholson and Von Rotberg, 1996; Pinniger, 1996; Zeuner, 1996).

Education and promotion

It is clear that the general public and their professional advisers are typically unaware of the potential hazards and risks associated with chemical treatments and associated residues. Despite the best efforts of individuals, groups and organisations, the message that such treatments and their residues can have an effect on the health of the building and its occupants, is not being widely considered.

A poster entitled "A guide to pesticide exposure for physicians" has been prepared, published and distributed by the Pesticide Exposure Group of Sufferers, giving details of symptoms of pesticide poisoning, treatment and useful addresses (PEGS, 1996a, 1996b). A similar poster is planned for community groups. Such information should also be considered by those responsible for designing or altering buildings.

In the long term, the solution for the increasing number of persons suffering from the effects of chemical sensitivity is to design specifically for their needs. The particular requirements of such environmentally and ecologically sensitive buildings have been considered by Nemeskeri *et al.* (1991), Crowther (1991) and Harland (1993), but the question of how to make existing buildings suitable for such sensitive occupancy, perhaps through a combination of containment, decontamination, selection of alternative materials and methods of construction, has yet to be fully addressed and answered.

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